Core Temperatures of Non-nesting Western Atlantic Seabirds

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ABSTRACT.— Core body temperatures of 23 species of birds collected off the North Carolina coast did not differ with sex, weight, time of day, or season. Within the orders Procellariiformes and Charadriiformes, there seems to be no correlation of temperature with mass. Temperature data on injured birds are similar to those of ones recently killed. Results of this study compared favorably with those obtained by other researchers and indicate no significant differences between body temperatures of foraging and non-incubating procellariiform birds at the nesting colonies. Temperature differences between birds taken at sea and those studied at nesting sites amount to about 1 °C and are best attributed to the activity state of the birds.

Little uniform information is available on deep-body temperatures of seabirds away from nesting colonies. Comparing thermal information collected by different investigators, using dissimilar methods and sampling variable locations within the body, presents interpretive difficulties. The opportunity to gather temperatures from a variety of species, using uniform methods and equipment, presented itself during a long-range study into the occurrence, seasonal distribution, and food habits of seabirds off the North Carolina coast (see Lee and Booth 1979). This paper is the first extensive report of core temperatures in actively foraging seabirds. It complements the works of others who obtained most of their information from nesting colonies, and for the most part substantiates their findings and speculations.

MATERIALS AND METHODS

Information was obtained between 1977 and 1982, primarily during spring, summer, and fall. Specimens were shot from boats traveling from 30 to 60 km off North Carolina's Outer Banks. Birds were then netted from the water and a thermistor probe (#418), feeding into a calibrated telethermometer (Yellow Springs Instruments), was inserted

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through the abdominal wall near the caudal part of the sternum deep into the viscera. The maximum time between downing of the bird and the insertion of the thermistor probe was 2 minutes. Body temperature (T_b) recordings stabilized within a maximum of 30 seconds of probe insertion. In order to determine if stress and shock affected core body temperature, readings were taken from any still-living birds before death and within 1 to 3 minutes of being shot. We also monitored the rate of cooling of six specimens for 20 minutes after death. Birds were later frozen in sealed plastic bags. After thawing in the laboratory, each bird was weighed to the nearest 0.1 g and sexed while being prepared for use in other studies. Level of significance is 0.05 for correlation coefficients of regressions and sample differences (using Student's *t*-test). Data are presented as mean ± 1 standard deviation.

RESULTS

Table 1 presents deep body temperatures and body mass of 23 species of seabirds representing 4 orders, 14 genera, and 250 individuals. Mean T_b of male and female seabirds (Table 2) were not significantly different. In Audubon's Shearwater, *Puffinus lherminieri*, and Cory's Shearwater, *Calonectris diomedea*, the only species with a field collecting base spanning 6 to 9 hours, T_b did not vary with time of day. However, we made no night collections. In both of these shearwaters, as well as in the Greater Shearwater, *Puffinus gravis*, T_b did not correlate with time of year. These three species were collected during the longest calendar sequences (April-November). Additionally, intraspecific regressions of body mass versus T_b were not significant.

Cooling curves were obtained on six birds ranging in size from 39.7 to 763.5 g (Fig. 1). As expected, large birds cooled more slowly than small ones. For example, in the first 20 minutes internal temperatures dropped less than 0.8 °C on *Pterodroma*-size birds. Four of six birds showed a slight and brief increase in T_b during the first minute or two. We think this temporary increase was the result of continued cellular heat production immediately after death in the absence of convective (respiratory and circulatory) avenues of heat loss. This initial increase in temperature may mask some heat loss owing to the elapsed time between death and T_b measurements. However, temperatures of living birds and recently dead ones showed no observable differences (Table 3).

DISCUSSION

In collecting temperature information we attempted to eliminate as many biases as possible. Activity states of the birds immediately prior to temperature measurements undoubtedly accounted for some of the variation in the procellariiform birds whose body temperatures were summarized by Warham (1971). The difference between resting/incubating and active procellariiform birds amounted to about 2 °C (Farner

Table 1. Deep body temperatures and body mass of seabirds. Mean ± one standard deviation (range in parentheses).

	N	Mass (g)	Body temperature (°C)
Gaviiformes			
Gavia immer	2	3588.0 ± 58.0 (3547.0-3629.0)	39.7 ± 0.2 (39.5-39.8)
Procellariiformes			
Fulmarus glacialis	20	692.3 ± 78.5 (550.0-860.0)	39.9 ± 0.8 (38.0-42.0)
Calonectris diomedea	35	591.6 ± 81.8 (430.4-749.5)	39.6 ± 0.9 (38.2-41.0)
Puffinus gravis	25	615.1 ± 103.7 (424.3-870.0)	39.8 ± 0.7 (38.6-41.2)
Puffinus lherminieri	35	206.6 ± 20.5 (138.4-242.0)	39.5 ± 1.0 (36.5-41.2)
Puffinus griseus	1	774.0	41.0
Pterodroma hasitata	9	441.5 ± 68.8 (352.3-496.0)	39.1 ± 0.6 (38.0-40.0)
Oceanites oceanicus	25	33.5 ± 3.5 (25.9-39.4)	38.9 ± 1.3 (37.0-42.2)
Pelecaniformes			
Phaethon aethereus	2	616.4 ± 12.1 (607.8-624.9)	39.3 ± 1.1 (38.5-40.0)
Sula bassanus	4	3396.0 ± 383.0 (2898.0-3750.0)	40.7 ± 0.9 (40.0-42.0)
Phalacrocorax auritus	2	1833.9 ± 96.7 (1765.5-1902.3)	40.4 ± 0.6 (39.9-40.8)
Charadriiformes			
Phalaropus lobatus	5	37.0 ± 5.9 (31.6-46.6)	39.9 ± 1.1 (38.8-41.5)
Phalaropus fulicaria	14	55.4 ± 9.9 (38.9-73.0)	40.3 ± 1.0 (38.2-42.6)
Stercorarius pomarinus	14	743.8 ± 58.7 (660.3-849.9)	40.4 ± 1.3 (38.4-43.3)
Stercorarius parasiticus	2	522.8 ± 9.3 (516.2-529.4)	42.0 ± 0.3 (41.8-42.2)
Larus marinus	4	1641.0 ± 89.8 (1577.0-1774.0)	39.7 ± 1.0 (39.2-41.2)
Larus argentatus	6	919.5 ± 120.7 (778.0-1114.5)	40.4 ± 0.5 (39.5-41.0)
Larus atricilla	11	333.7 ± 35.8 (277.9-424.6)	40.6 ± 1.3 (37.8-42.0)
Larus philadelphia	2	211.0 ± 7.1 (206.0-216.0)	39.3 ± 0.3 (39.1-39.5)
Rissa tridactyla	10	368.0 ± 60.5 (294.7-448.4)	40.2 ± 0.6 (39.4-41.2)
Sterna hirundo	7	118.0 ± 14.4 (95.5-142.4)	40.8 ± 1.1 (39.0-42.5)
Sterna anaethetus	6	135.5 ± 15.4 (117.9-154.3)	40.4 ± 0.8 (39.2-41.8)
Sterna maxima	9	489.5 ± 29.2 (456.7-543.1)	40.1 ± 1.1 (38.0-41.1)

1956; Farner and Serventy 1959; Grant and Whittow 1983; Howell and Bartholomew 1961a,b; Warham 1971). Warham (1971) expressed doubt that the T_b of petrels flying at sea would be greatly increased, because of their energy-efficient methods of flight. Most of the temperatures presented here are from birds collected in flight, although some of the phalaropes were collected on the water. Nevertheless, most of the phalaropes were actively foraging (i.e. swimming) rather than resting on the surface. We have no way of knowing how long an individual bird had been active or how long it had been resting before collection. Avian flight (especially in birds that do not soar) typically elevates body temperatures 1 to 2 °C above the level recorded for resting birds

Table 2. Body temperatures of male and female seabirds. Means not significantly different at $P > 0.05$.

	Male		Female	
Species	N	°C ± 1SD	N	°C ± 1SD
Fulmarus glacialis	7	39.7 ± 1.0	13	40.0 ± 0.8
Calonectris diomedea	15	39.6 ± 0.9	15	39.7 ± 0.9
Puffinus gravis	7	39.6 ± 0.7	15	39.9 ± 0.8
Puffinus lherminieri	15	39.3 ± 1.3	15	39.6 ± 0.7
Oceanites oceanicus	9	38.6 ± 1.2	12	38.6 ± 1.2
Stercorarius pomarinus	4	40.1 ± 2.2	9	40.3 ± 1.0
Larus atricilla	4	41.3 ± 0.8	6	39.9 ± 1.4
Rissa tridactyla	4	40.3 ± 0.9	6	40.1 ± 0.4

(Berger and Hart 1974). The maximum T_b of flying birds can be seen in the upper part of the T_b range of Table 1. The T_b of seven petrel species averaged 39.7 ± 0.7 °C, which is only about 0.9 °C higher than the mean compiled for 31 species by Warham (1971). This slight and insignificant difference may result from one or more of the following: activity states of the bird, different investigator's techniques, and positioning of temperature probes (cloacal, preventricular, or visceral). We suspect, however, that it reflects the larger percentage of active birds in our samples than in samples compiled by investigators working with nesting colonies. We found no body mass, sexual, seasonal, or hourly differences in T_b within species.

McNab (1966:54) argued that the "apparent correlation between the level of body temperature and the taxonomic group is really a correlation of weight and taxonomic group. (It should be noted that within both the ratites and penguins, small species have higher body temperatures than large species)." Warham (1971) presented evidence that the mean body temperature of petrels is significantly lower than that of non-procellariiform birds. Within the order Procellariiformes, regression of T_b against body weight for our temperature (Table 1) likewise shows no correlation. Small petrels do not have higher body temperatures than do large ones, as Warham illustrated. This is true for our Charadriiformes as well. Our temperatures agree closely with the range of body temperatures reported by Dawson and Hudson (1970) for the orders Gaviiformes, Procellariiformes, Pelecaniformes, and Charadriiformes.

We found no evidence that stress and shock affected the body temperatures of still-living birds within 1 to 3 minutes after they were shot. The T_b's did not differ from those of recently expired birds (Table 3).

Table 3. Body temperatures and masses of dead and live birds.

Species	Dead			Live		
	Temperature		Mass	Temperature		Mass
	N	°C ± 1SD	g ± 1SD	N	°C ± 1SD	g ± 1SD
Calonectris diomedea	35	39.6 ± 0.9	591.6 ± 81.8	12	39.5 ± 0.7	577.5 ± 66.6
Puffinus lherminieri	35	39.5 ± 1.0	206.6 ± 20.5	16	39.9 ± 0.9	208.9 ± 22.7
Pterodroma hasitata	9	39.1 ± 0.6	441.5 ± 68.8	3	39.8 ± 0.7	491.1 ± 34.6
Oceanites oceanicus	25	38.9 ± 1.3	33.5 ± 3.5	8	38.6 ± 1.8	32.2 ± 2.6
Phalaropus lobatus	5	39.9 ± 1.1	37.0 ± 5.9	5	40.9 ± 1.2	38.9 ± 6.7
Phalaropus fulicaria	14	40.3 ± 1.0	55.4 ± 9.9	7	40.9 ± 0.9	51.8 ± 9.0
Sterna hirundo	7	40.8 ± 1.1	118.0 ± 14.4	4	41.4 ± 0.8	127.3 ± 20.1
Sterna anaethetus	6	40.4 ± 0.8	135.5 ± 15.4	3	40.6 ± 1.1	127.6 ± 5.5

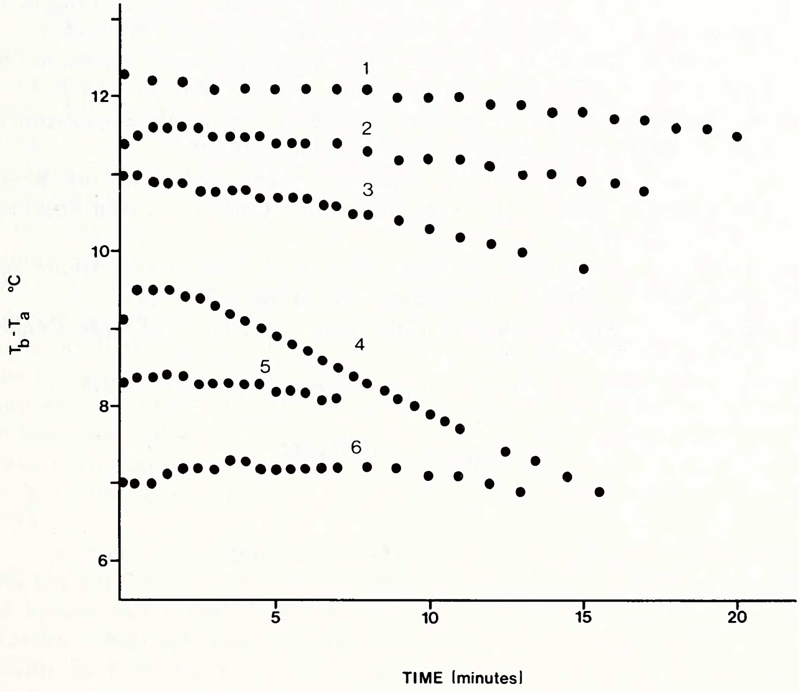

Fig. 1. Cooling curves of six seabirds of various masses. Zero time is time of death. 1. *Pterodroma*, 448.9 g. 2. *Pterodroma*, 459.0 g. 3. *Puffinus lherminieri*, 221.9 g. 4. *Oceanites oceanicus*, 39.7 g. 5. *Calonectris diomedea*, 763.5 g. 6. *Puffinus lherminieri*. 232.5 g.

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